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AN ECONOMY TEST
OF
$4\frac{1}{2}'' \times 4\frac{1}{2}''$ NEW-WAY ENGINE

A THESIS SUBMITTED TO

THE FACULTY OF THE TOWNE SCIENTIFIC SCHOOL

OF

THE UNIVERSITY OF PENNSYLVANIA

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

BY

EMIL P. GOHN and WILLIAM J. DOUGHERTY

JUNE, 1926

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T 26 Mech. Eng. Dept. G., Emil Peter & I., William James Gas engines

INTRODUCTION

The test of the "New Way" Engine was made with three objects in view:

Knowing that the engine was about five years old and had two thesis performed on it, it was decided to perform the following test.

1- A determination of the economy of the engine at various speeds and loads.

2- Comparison of the economy of gasoline and kerosene as fuels.

3- To secure rated horse power output of the machine without any separate cooling apparatus.

The engine is made by the "New Way" Engine Company of Lansing, Michigan, and is designed to run on kerosene, to be started with gasoline. However, the engine runs very well on the latter fuel. Tests were made with both fuels, the runs being performed under the same conditions so as to compare the economies of the two fuels.

In the last thesis full rating was obtained only after forcing more air around the cylinder; therefore, it was thought advisable to attempt this test without extra cooling devices.

DESCRIPTION OF APPARATUS.

The engine is a single cylinder, four cycle, vertical type. The S.A.E. rating is 5 Horse Power with bore and stroke of 4½ inches each. The speed range is from 450 R.P.M. to 900 R.P.M. It was difficult to run below 500 R.P.M. or above 900 R.P.M.

The simplicity of the engine makes it very deisrable for farm use where it gets very little attention. It can be used for light farm work and may also be connected to a lighting outfit. Since it is aircool, no water is required. The cooling is accomplished by passing air around the cylinder by means of fan blades attached to the flywheel. The cylinder is provided with fins to give more cooling area, and a casing surrounds part of the cylinder, forcing the air to go through the spaces between the fins.

The cylinder is of the "L" head type. The inlet valve is operated automatically by suction, while the exhaust valve is controlled by a cam and push-rod arrangement. The piston is of cast iron.

The cylinder walls are lubricated from an oil cup which feeds oil directly on them; while the main bearings, cams, gears, etc., are lubricated by the splash system from the crank case.

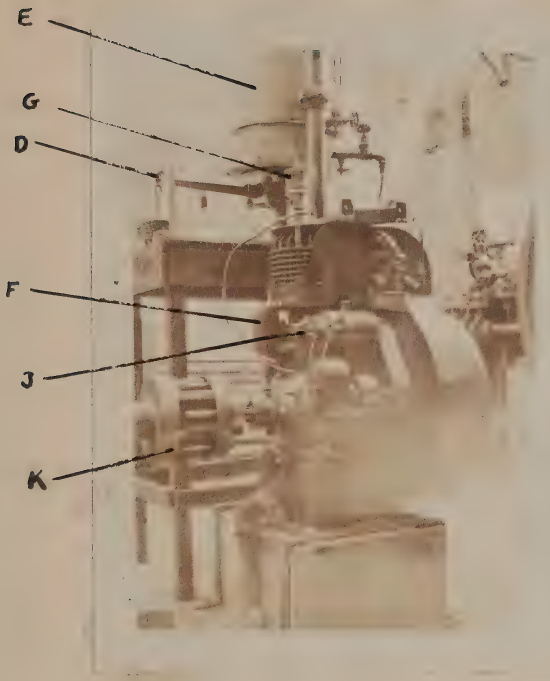
A centrifugal ball governor which operates a butterfly valve in the carburetor controls the speed of the engine.

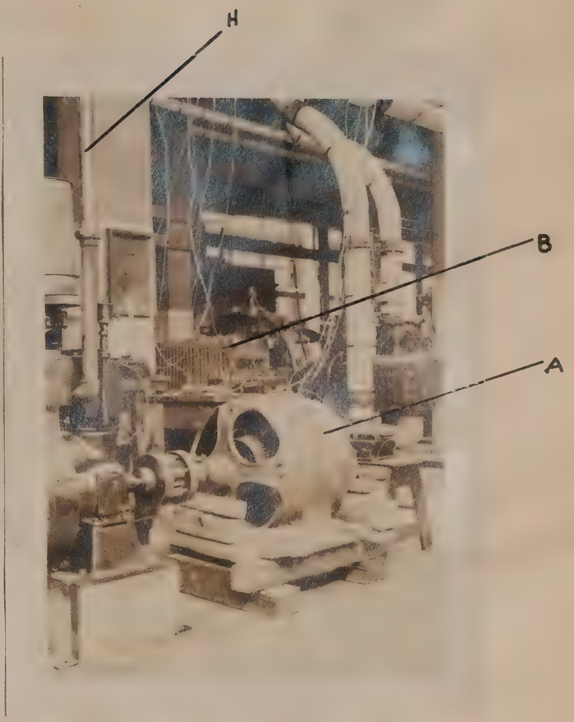
This governor can be controlled by hand by varying the compression on a spring which resists the centrifugal action of the governor weights. The speed regulation is very close, therefore, this engine is suitable for lighting outfits.

The carburetor is of the Holly simple jet type, the mixture being controlled entirely by means of a needle valve. Ignition is of the high tension type, the magneto being driven by a flexible coupling on the counter shaft.

For loading the engine a generator separately excited was directly connected. Resistance frames in parallel were used to dissipate the energy. By means of separate excitation it was possible to obtain constant field current and therefore easy to obtain the stray-power losses from the curves.

PLATE - 1 -





A - Generator
B - Resistance Frames
C - Table for Electrical Instruments
D - Scale to weigh Fuel
E - Fuel Tank
F - Oil Seperator
G - Oil Cup
H - Exhaust Pipe
J - Lever for controlling Spark
K - Flexible Coupling

PREPARATION OF TEST

About three-quarters of the time alloted for the actual thesis work was spent in preparation. The engine itself was subjected to a complete inspection and overhauling which consisted of cleaning parts, draining out the crank case, removal of carbon from the piston head, renewal of gaskets, oiling, etc.

A five horse-power electric motor was first connected to the engine, but after some preliminary running, the motor was found to be faulty, so that a new one had to be obtaining and lined up. A bushing had to be made to hold the coupling on the shaft, and the concrete foundation had to be fastened to the floor by means of steel brackets. A two-inch exhaust pipe from the engine was joined to an exhaust header common to several laboratory motors. The wiring of the electrical apparatus and the setting up of the fuel tank and weighing device completed the preliminary work.

CONDUCT OF THE TEST

The engine was connected to a ten horse-power electrical motor. This motor was run as a generator separately excited. The armature resistance was found and also the stray power losses were obtained at various speed and for various valued of the field current. The scheme of the test was to convert the power into electric energy and to dissipate this energy by means of resistance frames.

The field current was provided with a field rheostat to keep the current constant, and an ammeter was used to measure the value of this field current. The electrical generator being run at much below rating, it was necessary to obtain the stray-power and the RI^2 losses. Knowing these values, it was possible to obtain the output of the engine.

A tachometer was used to obtain the speed, and an ammeter and voltmeter were used to obtain values of current and voltage respectively. The fuel tank was placed on a platform scale and increments of 8 ounces were taken as runs. The runs average about ten minutes duration, and the readings were taken every two minutes. All the instruments used in the test were calibrated and the curves are shown in the appendix.

After running the engine under load for a while, the cylinder became very hot so that it was impossible to obtain rated load, and three-quarters rated load was obtained only with a

great deal of knocking due, no doubt, to preignition. This showed that the cooling apparatus provided by the fan is not adequate to take care of the great amount of heat at the high loads.

The friction horse-power of the engine at various speeds was obtained by driving the engine by means of the motor with the compression on.

No trouble was experienced during the test except that of knocking mentioned before. Oil in the crank case and oil cup was drained out and refilled at frequent intervals. The engine started readily on gasoline and ran on kerosene without using the air preheater. The governor provided by the engine controlled the speed very closely.

HEATING VALUE OF GASOLINE

Formula $H = 18320 + 40\ (Be' - 10)$

For every 10 above 60 F, subtract 1° Be'

For every 10 below 60 F, add 1° Be"

Heating Value = 18320 40 (58.5 - 1.8-10) = 20,190 B.T.U./#

HEATING VALUE OF KEROSENE

FORMULA H = 18,440 + 40(45-2.3-10) = 19,750 B.T.U./#

STRAY POWER LOSS

E.I. (No Load) = Stray Power $R_a I_a^2$

Stray Power = E.I. - $R_a I_a^2$

$= 40.5 \times 5 - 0.1 \times 5^2 = 0.268$ H.P.

FRICTION HORSE POWER

F.H.P. = Input to Motor in Watts - Stray Power Loss-$R_a I_a^2$ loss

$= \frac{\text{Watts}}{746}$

Example - 600 R.P.M.

Input to Motor = 59x14.5 = 856 Watts

Stray Power From Curve = 322 Watts

$R_a I_a^2$ Loss From Curve = 21 Watts

Friction Horse Power = $856 - (322 + 21) = \frac{513}{746} = 0.687$ H.P.

BRAKE HORSE POWER OF ENGINE

B.H.P. = Output of Generator Stray Power $R_a I_a^2$ Loss

Example at 820 R.P.M. - Gasoline

Output of Generator = 72.5 x 5.1 = 370 Watts

Stray Power From Curve = 510 Watts

$R_a I_a^2$ From Curve = 6 Watts

B.H.P. = $\frac{886}{746}$ Watts = 1.185 H.P.

MECHANICAL EFFICIENCY

$$\text{Mechanical Efficiency} = \frac{\text{B.H.P}}{\text{B.H.P.} + \text{F.H.P.}}$$

Example 820 R.P.M. - Gasoline

B.H.P. = 1.185 F.H.P. = 0.992 (From Curve)

$$\text{Mechanical Efficiency} = \frac{1.185}{1.185 + 0.992} = \frac{1.185}{2.177} = 54.5\%$$

THERMAL EFFICIENCY ON B.H.P.

$$\text{Thermal Efficiency} = \frac{\text{B.T.U./B.H.P. Hr.}}{\text{\# Fuel /B.N.P. Hr. x B.T.U./\#}}$$

B.T.U./B.H.P. = 2545

# Fuel /B.H.P. Hr. = 1.98

B.T.U./# Fuel = 20,190

$$\text{Thermal Efficiency} = \frac{2545}{1.98 \times 20{,}190} = 6.38\%$$

COST OF FUEL PER B.H.P./Hr

Cost per B.H.P./Hr. = Cost of fuel /lb. x lbs./ B.H.P./Hr.

Lbs. fuel per B.H.P. /Hr.= 1.98 lbs.

Cost per Gallon = $0.24

Specific Gravity = $\frac{140}{130 + 46.7}$ Gasoline = $\frac{140}{176.7}$ = 0.793

# per Gallon = $\frac{0.793 \times 62.3}{7.46}$ = 6.61 lbs.

Cost of fuel ¢ per # = $\frac{24}{6.61}$ = 3.63¢

Cost of Fuel per B.H.P./Hr. = 3.63 x 1.98 = 7.2¢

COST OF KEROSENE

Cost per B.H.P./H.R. = Cost of fuel /lb. x lbs./B.H.P. /Hr.

Specific Gravity = $\frac{140}{130 + 45}$ = $\frac{140}{175}$ = 0.8

# per Gallon = $\frac{0.8 \times 62.3}{7.46}$ = 6.67

Cost of fuel ¢/# = $\frac{19¢ /gal.}{6.67}$ = 2.84¢

Cost of fuel /B.H.P. / Hr. = 2.84 x 1.8 #/B.H.P. /Hr. = 5.1¢

SAMPLE DATA SHEET

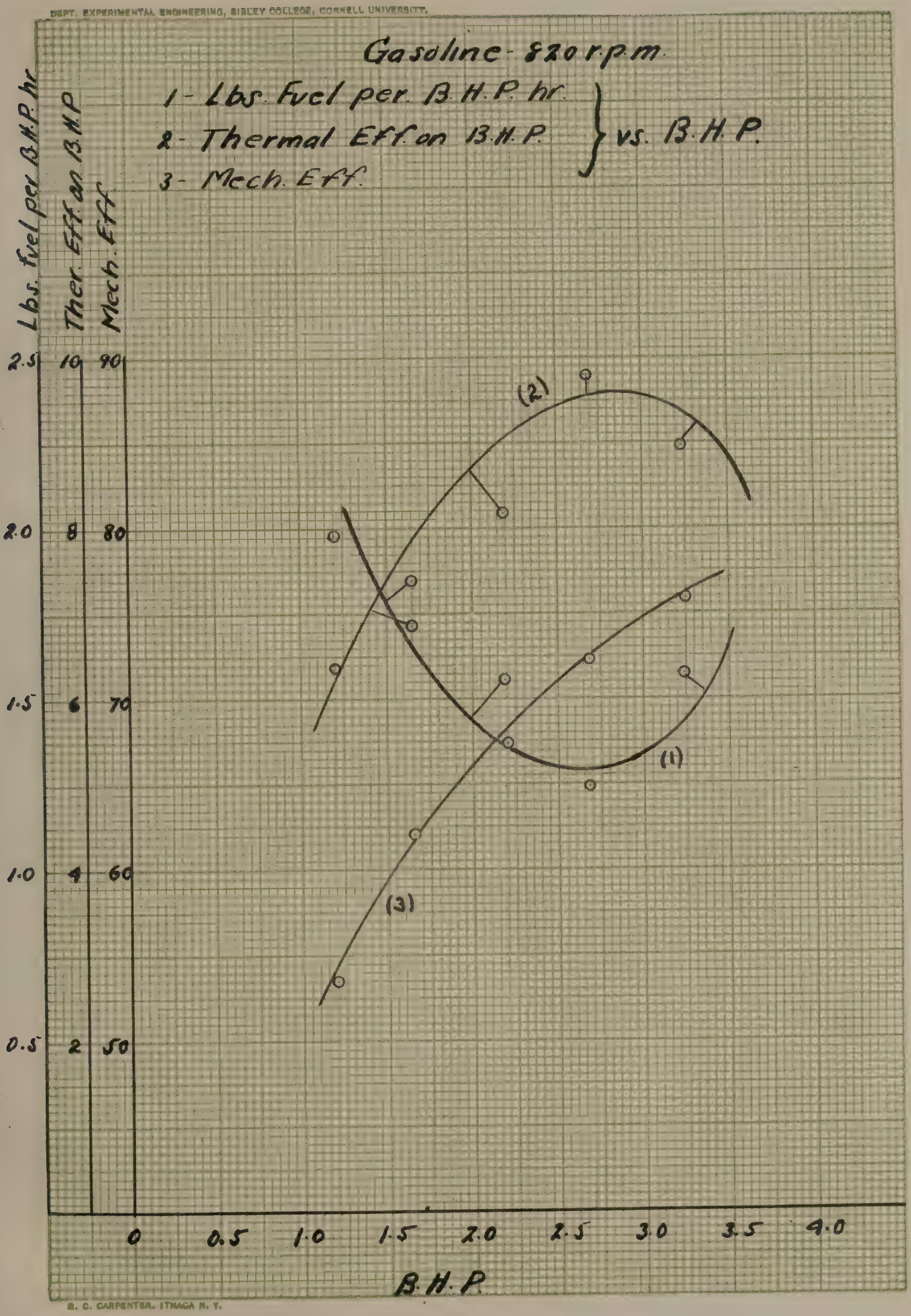
GASOLINE RUN Be'-58.5 TEMPERATURE 78° F.

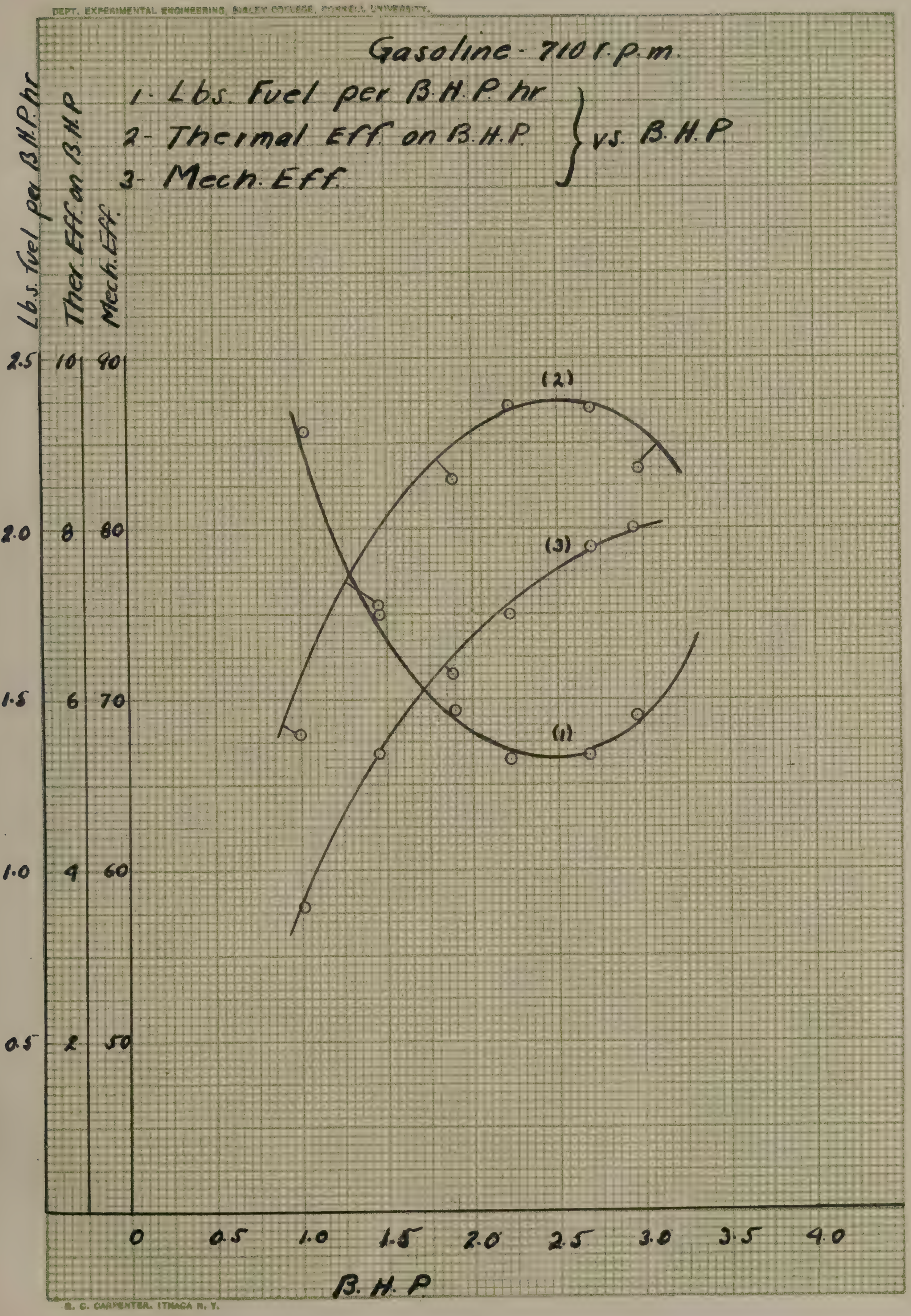
TIME	R.P.M.	GASOLINE		ARM. CURRENT AMPS.	ARM. VOLTS	STRAY POWER WATTS	APPROX. H.P.
		Lbs.	Oz.				
28:00	820	21	9.0	5.0	73.0	510	1.18
32:00	820	21	7.5	5.0	73.5	510	1.18
34:00	820	21	6.0	5.1	73.0	510	1.18
36:00	820	21	4.5	5.1	73.5	510	1.18
38:00	820	21	3.2	5.1	73.5	510	1.18
40:00	820	21	1.5	5.1	73.5	510	1.18
40:45	820	21	1.0	5.1	73.5	510	1.18

TABLE OF RESULTS GASOLINE						
RUN	BRAKE H.P.	# FUEL /BRAKE H.P.	THERM. EFF.on BRAKE H.P.	MECH. EFF.	R.P.M.	COST in ¢ per BRAKE H.P.Hr.
1	1.185	1.98	6.38%	53.5%	820	7.2
2	1.675	1.85	6.83%	62.0%	820	6.7
3	2.190	1.55	8.13%	68.1%	820	5.6
4	2.690	1.24	9.83%	72.3%	820	4.5
5	3.230	1.59	7.95%	76.0%	820	5.7
1	1.020	2.28	5.53%	58.0%	710	8.3
2	1.460	1.78	7.10%	66.8%	710	6.5
3	1.850	1.47	8 60%	71.5%	710	5.3
4	2.210	1.33	9.50%	75.0%	710	4.8
5	2.700	1.35	9.40%	79.0%	710	4.9
6	2.950	1.45	8.70%	80.0%	710	5.2
1	0.840	1.60	7.90%	55.0%	600	5.8
2	1.210	1.29	9.80%	64.0%	600	4.7
3	1.650	1.07	11.80%	70.0%	600	3.9
4	2.040	1.25	10.10%	74.5%	600	4.5
5	2.320	1.45	8.70%	77.0%	600	5.2

TABLE OF RESULTS - KEROSENE

RUN	BRAKE H.P.	#FUEL /BRAKE H.P.	THERM. EFF.on BRAKE H.P.	MECH. EFF.	R.P.M.	COST in ¢ per BRAKE H.P.Hr.
1	1.23	1.80	7.15%	55.0%	820	5.10
2	1.69	1.45	8.88%	62.0%	820	4.15
3	2.13	1.32	9.75%	67.2%	820	3.75
1	1.03	1.69	7.63%	50.0%	720	4.80
2	1.45	1.42	9.07%	58.2%	720	4.12
3	1.79	1.42	9.07%	63.5%	720	4.12
4	2.12	1.38	9.35%	67.0%	720	3.92
1	0.84	2.06	6.25	55.0%	620	5.85
2	1.27	1.56	8.10%	64.4%	620	4.45
3	1.54	1.43	9.18%	71.0%	620	4.06


DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
Gasoline - 820 r.p.m.
1 - Lbs. Fuel per. B.H.P. hr.
2 - Thermal Eff. on B.H.P.
3 - Mech. Eff.
vs. B.H.P.
Lbs. fuel per B.H.P. hr.
Ther. Eff. on B.H.P.
Mech. Eff.
2.5
10
90
2.0
8
80
1.5
6
70
1.0
4
60
0.5
2
50
(1)
(2)
(3)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
B.H.P.
B. C. CARPENTER, ITHACA N. Y.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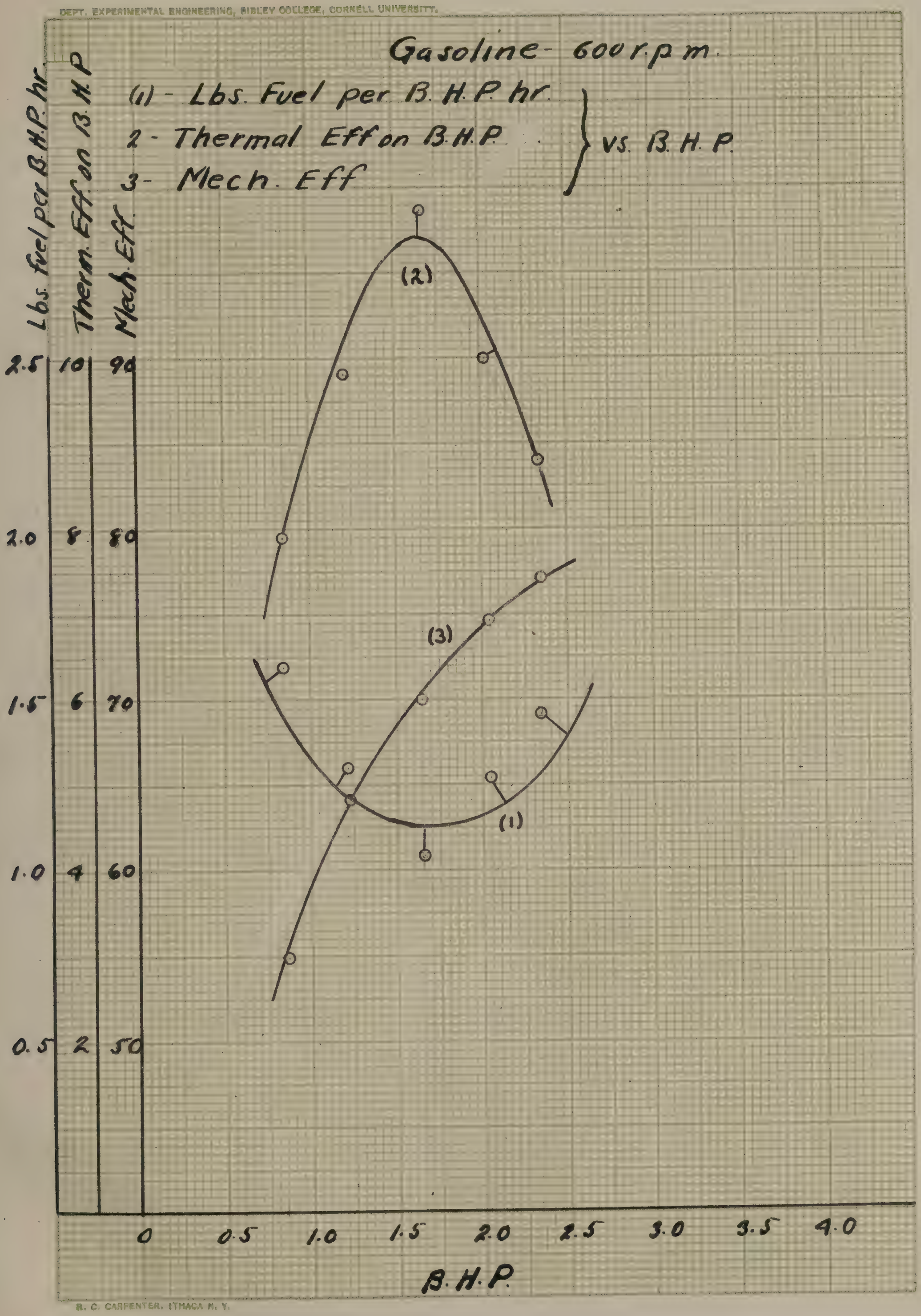
Gasoline - 710 r.p.m.
1- Lbs. Fuel per B.H.P. hr
2- Thermal Eff. on B.H.P.
3- Mech. Eff.
vs. B.H.P.
Lbs. Fuel per B.H.P. hr
Ther. Eff. on B.H.P.
Mech. Eff.
2.5
10
90
2.0
8
80
1.5
6
70
1.0
4
60
0.5
2
50
(2)
(3)
(1)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
B. H. P.
B. C. CARPENTER, ITHACA N. Y.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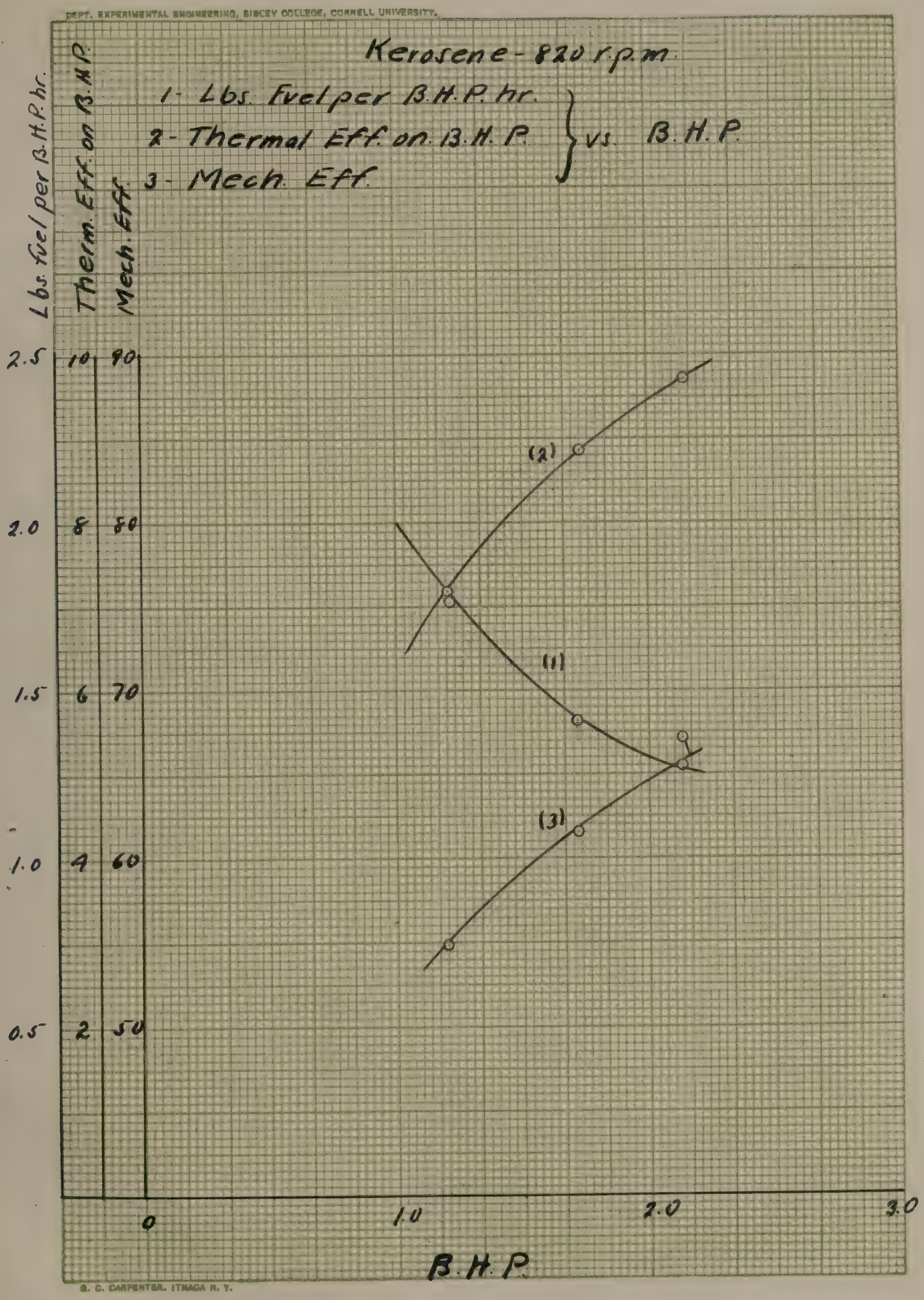
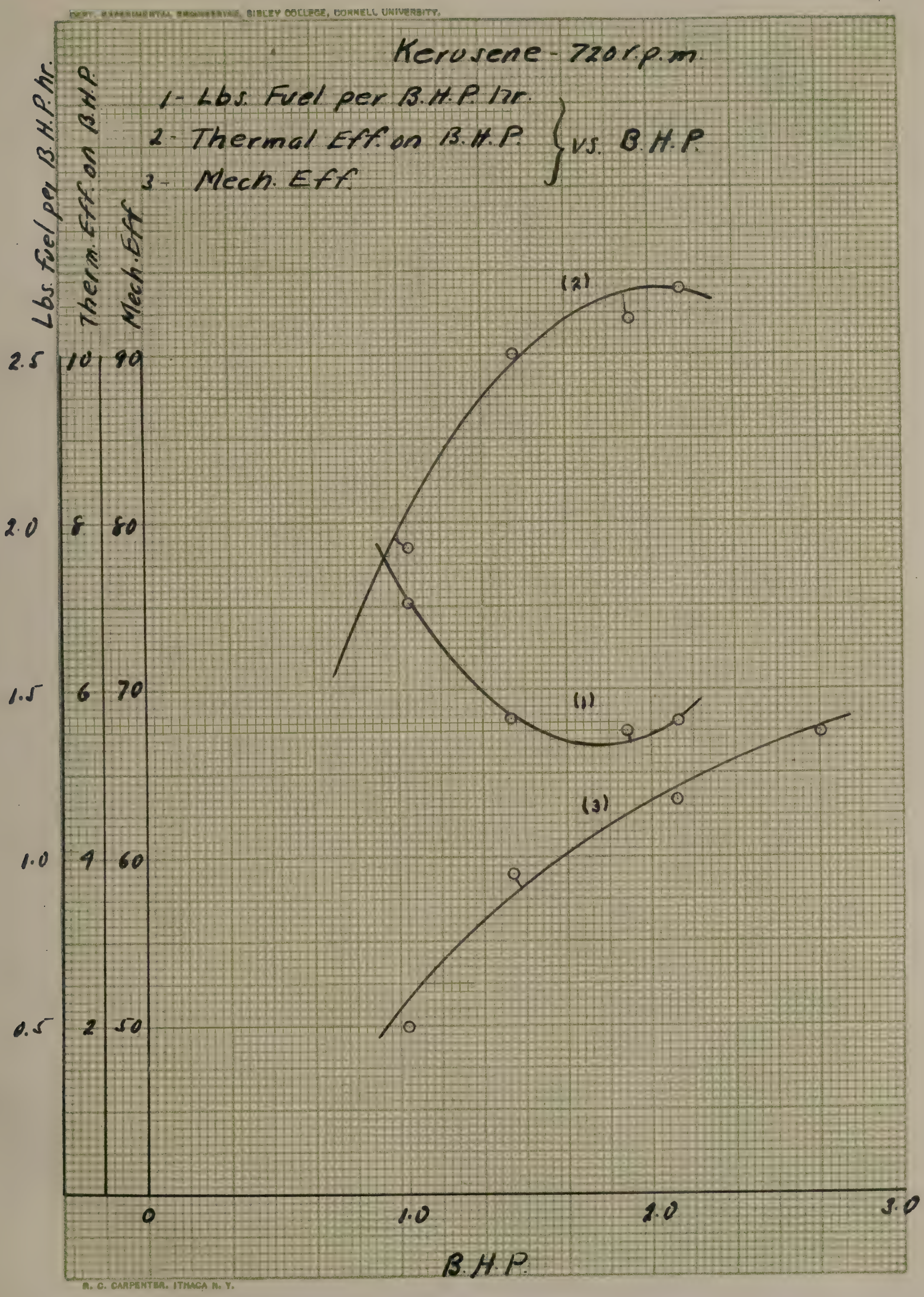
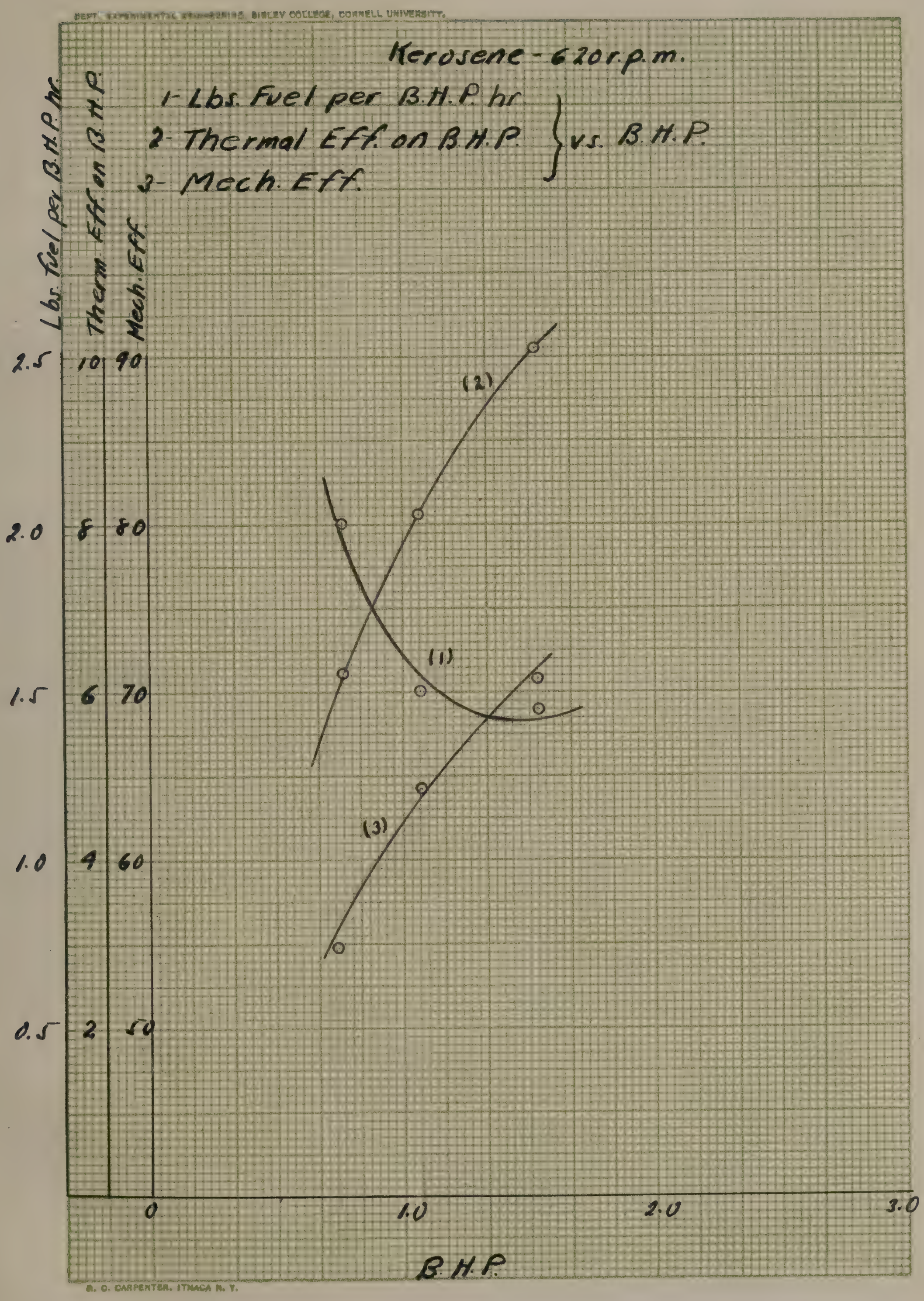
Gasoline- 600 r.p.m.
(1) - Lbs. Fuel per B.H.P. hr.
2 - Thermal Eff on B.H.P.
3 - Mech. Eff
vs. B.H.P.
Lbs. fuel per B.H.P. hr.
Therm. Eff on B.H.P.
Mech. Eff.
2.5
10
90
2.0
8
80
1.5
6
70
1.0
4
60
0.5
2
50
(2)
(3)
(1)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
B.H.P.
R. C. CARPENTER, ITHACA N. Y.


DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
Kerosene - 820 r.p.m.
1- Lbs. Fuel per B.H.P. hr.
2- Thermal Eff. on B.H.P.
3- Mech. Eff.
vs. B.H.P.
Lbs. fuel per B.H.P. hr.
Therm. Eff. on B.H.P.
Mech. Eff.
2.5
2.0
1.5
1.0
0.5
10
8
6
4
2
90
80
70
60
50
(1)
(2)
(3)
0
1.0
2.0
3.0
B.H.P.
B. C. CARPENTER, ITHACA N. Y.


DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
Kerosene - 720 r.p.m.
1 - Lbs. Fuel per B.H.P. hr.
2 - Thermal Eff. on B.H.P.
3 - Mech. Eff.
vs. B.H.P.
Lbs. Fuel per B.H.P. hr.
Therm. Eff. on B.H.P.
Mech. Eff.
2.5
10
90
2.0
8
80
1.5
6
70
1.0
4
60
0.5
2
50
0
1.0
2.0
3.0
B.H.P.
(1)
(2)
(3)
R. C. CARPENTER, ITHACA N. Y.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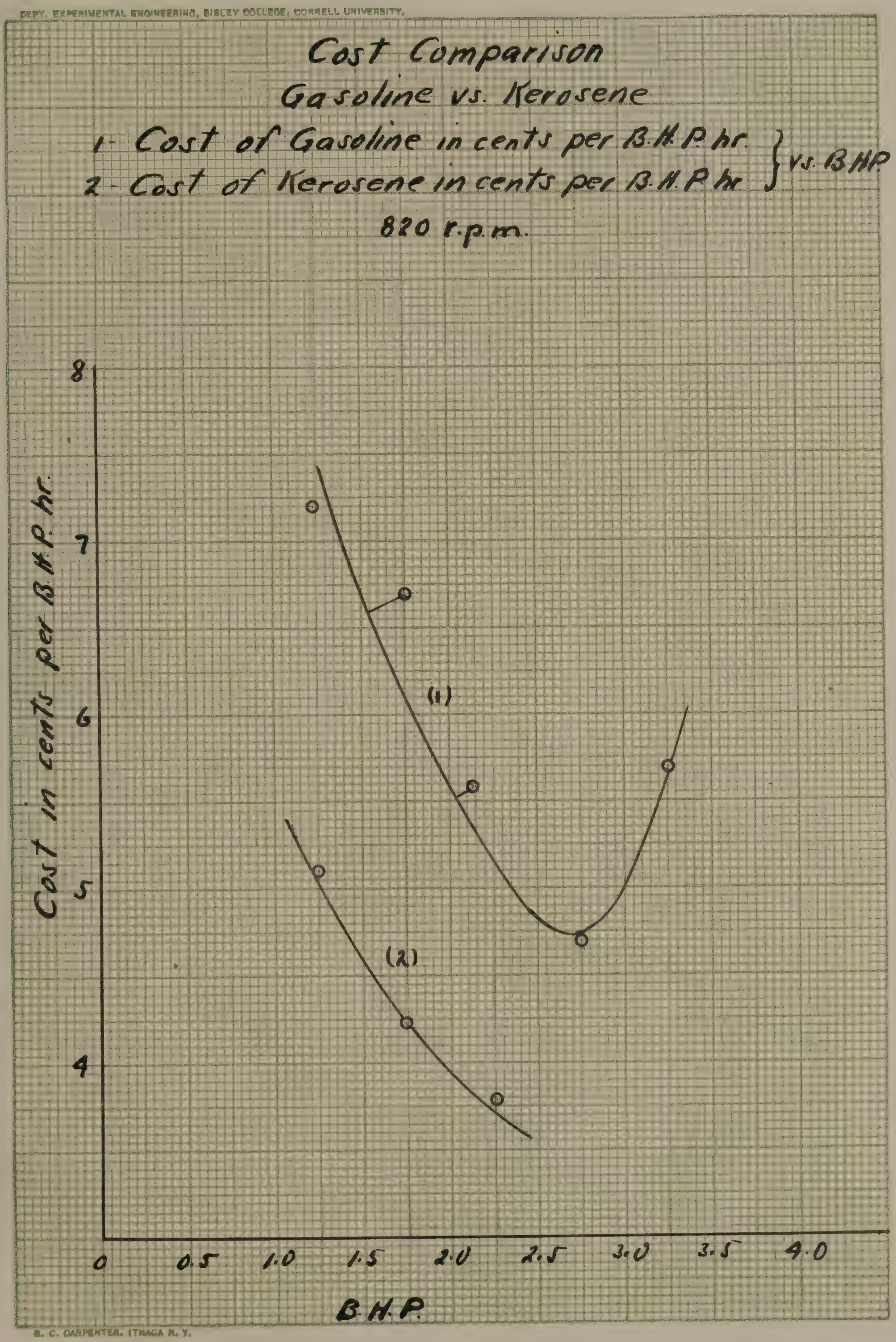
Kerosene - 620 r.p.m.
1- Lbs. Fuel per B.H.P. hr.
2- Thermal Eff. on B.H.P.
3- Mech. Eff.
vs. B.H.P.
Lbs. Fuel per B.H.P. hr.
Therm. Eff. on B.H.P.
Mech. Eff.
2.5
10
90
2.0
8
80
1.5
6
70
1.0
4
60
0.5
2
50
0
1.0
2.0
3.0
B.H.P.
(1)
(2)
(3)
B. C. CARPENTER. ITHACA N. Y.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Cost Comparison

Gasoline vs. Kerosene

1 - Cost of Gasoline in cents per B.H.P. hr.
2 - Cost of Kerosene in cents per B.H.P. hr. } vs. B.H.P.

820 r.p.m.

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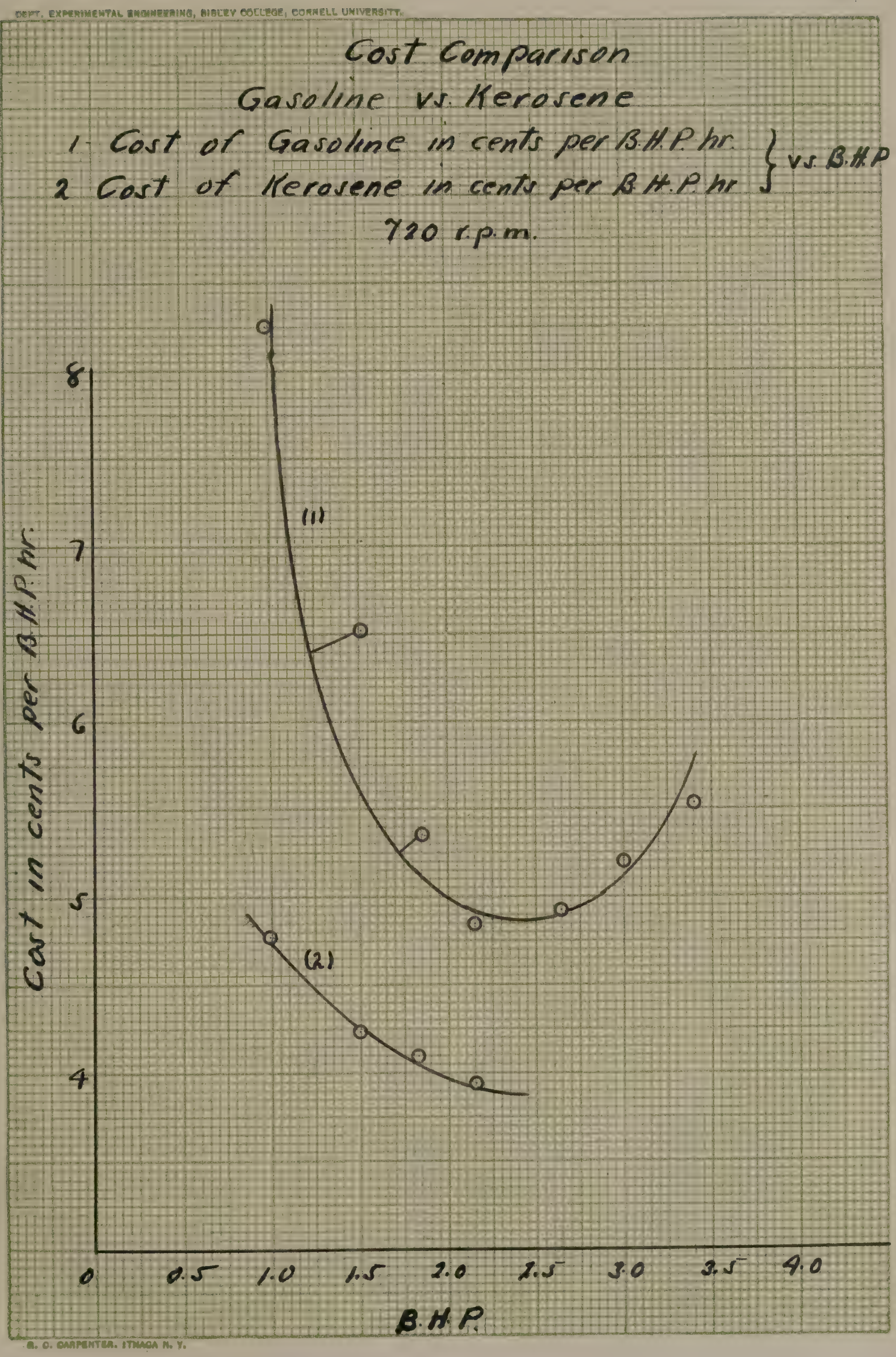
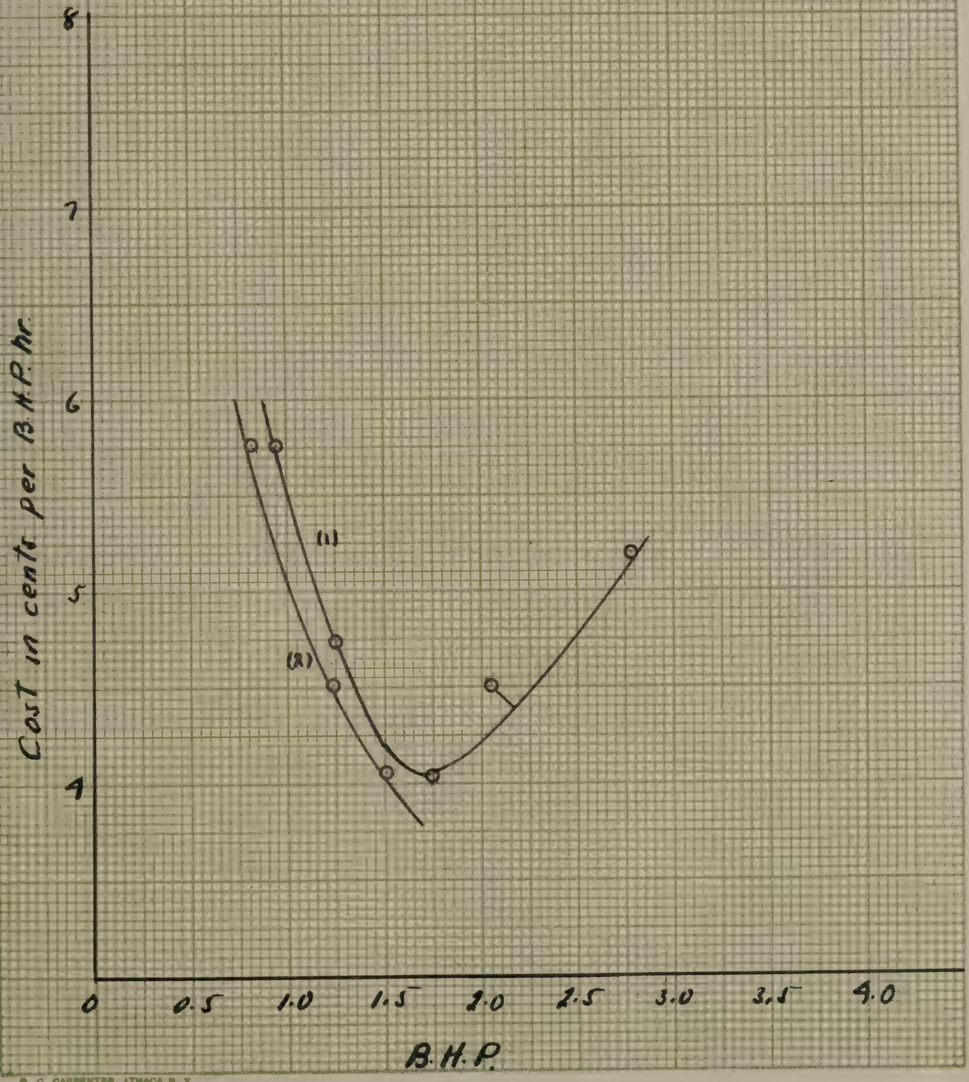

DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
Cost Comparison
Gasoline vs. Kerosene
1 Cost of Gasoline in cents per B.H.P. hr.
2 Cost of Kerosene in cents per B.H.P. hr.
vs. B.H.P
720 r.p.m.
Cost in cents per B.H.P. hr.
8
7
6
5
4
(1)
(2)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
B.H.P.
B. C. CARPENTER, ITHACA N. Y.

DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.

Cost Comparison
Gasoline vs. Kerosene

1- Cost of Gasoline in cents per B.H.P. hr.
2- Cost of Kerosene in cents per B.H.P. hr. } vs. B.H.P.

620 r.p.m.



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DISCUSSION OF RESULTS.

In discussin the results it is best to refer back to the curves. All values are referred to brake horse-power, since indicated horse-power means very little when talking about an internal combustion engine. Although the governor gives good speed regulation, the engine being built for farm work lacks the niceties of control by means of which smooth curves can be obtained during test. However, with little attention to the motor, the curves as obtained show surprising regularity. They follow the laws of thermodynamics and the mechanical efficiency increases in every case with an increase in the brake horse-power, which should be the case.

The peculiar shape to the curves of the 820 R.P.M. run is due, no doubt, to preignition which was encountered while rated load was being approached. From the curves it is seen that the best efficiences are obtained around 2¾ horse-power. The curves of the 700 R.P.M run are the best of the lot, which shows that the engine runs the best at this speed, giving the smooth curves as shown. Here also best results are obtained at a brake horse-power corresponding to those of the 820 R.P.M. run. The sudden drop in the efficiency curve and the sudden rise in the fuel consumption curve at 3 horse-power is due to preignition.

When going to the lower speeds that is from 600 R.P.M.

down, the curves become very irregular. This is due to the fact that the engine is running under conditions not suitable for best results. However, the lowest fuel consumption and highest thermal efficiency were reached at 600 R.P.M. and around 1$\frac{3}{4}$ horse-power. To run the engine at loads other than this, it becomes very uneconomical as shown by the curves.

The first thing that is noticeable in the kerosene runs is that at the various speeds, the range in loads were very limited. As seen from the curves, the highest brake horse-power obtainable was about 2$\frac{1}{4}$ which is less than 50% rating of the machine. Loads above this were obtained only when the engine was cool and this lasted only for a short time until it heated up again and then preignition resulted.

However, both the thermal efficiency and the fuel consumption for corresponding speed and loads are better for kerosene than for gasoline. This should be the case, since the engine was designed to run with kerosene as a fuel. As can be expected, the fuel costs for kerosene are much lower than those for gasoline. A surprisingly low value of cost is obtained for kerosene and the slope of the curve is such that they have a tendency to still give lower values but the knocking of the engine as the load increased made it impossible to get to the bottom of the curves.

It can be seen that if some means could be had for cooling the cylinder to prevent preignition, a very low fuel consumption might be obtained. The time, however, was too short for the installation of an additional cooling device.

One of the purposes of the test, as was stated in the introduction, was to obtain rated output of the engine without any separate cooling device. Time and again it was attempted to get at least 90 percent rating when the engine was cool, but as soon as 60 percent rating was reached, preignition would occur and any further increase in the load would stall the engine. Of course, one must not lose sight of fact that the test was performed in a laboratory the temperature of which never was below 80° F.

In concluding, therefore, it is evident that if this motor is used indoors, some improvement should be made in the cooling apparatur if rated output is to be obtained. With this improvement, however, and the little attention that the motor requires, the good fuel economies should make this motor very popular for light farm work and lighting outfits.

- APPENDIX -

RESISTANCE OF GENERATOR ARMATURE

ARMATURE CURRENT	5.75	10.25	14.35	19.10	25.00
ARMATURE VOLTAGE	0.51	1.01	1.45	1.94	2.50
RESISTANCE	0.099	0.098	0.101	0.102	0.100

AVERAGE RESISTANCE OF ARMATURE - - - - 0.100 OHMS

FRICTION HORSEPOWER OF ENGINE

ENGINE R.P.M.	ARM. VOLTS.	ARM. AMPS.	INPUT in WATTS	$R_aI_a^2$ LOSS WATTS	STRAY POWER LOSS WATTS	INPUT to ENGINE WATTS	FRICTION H.P.
650	53.6	4.66	250	2.16	270	522	0.70
700	58.8	4.30	253	1.84	290	545	0.73
720	59.5	4.25	253	1.92	305	560	0.75
755	61.6	4.75	293	2.25	310	605	0.81
770	53.5	4.92	313	2.40	320	635	0.85
805	72.5	5.06	367	2.50	340	710	0.95

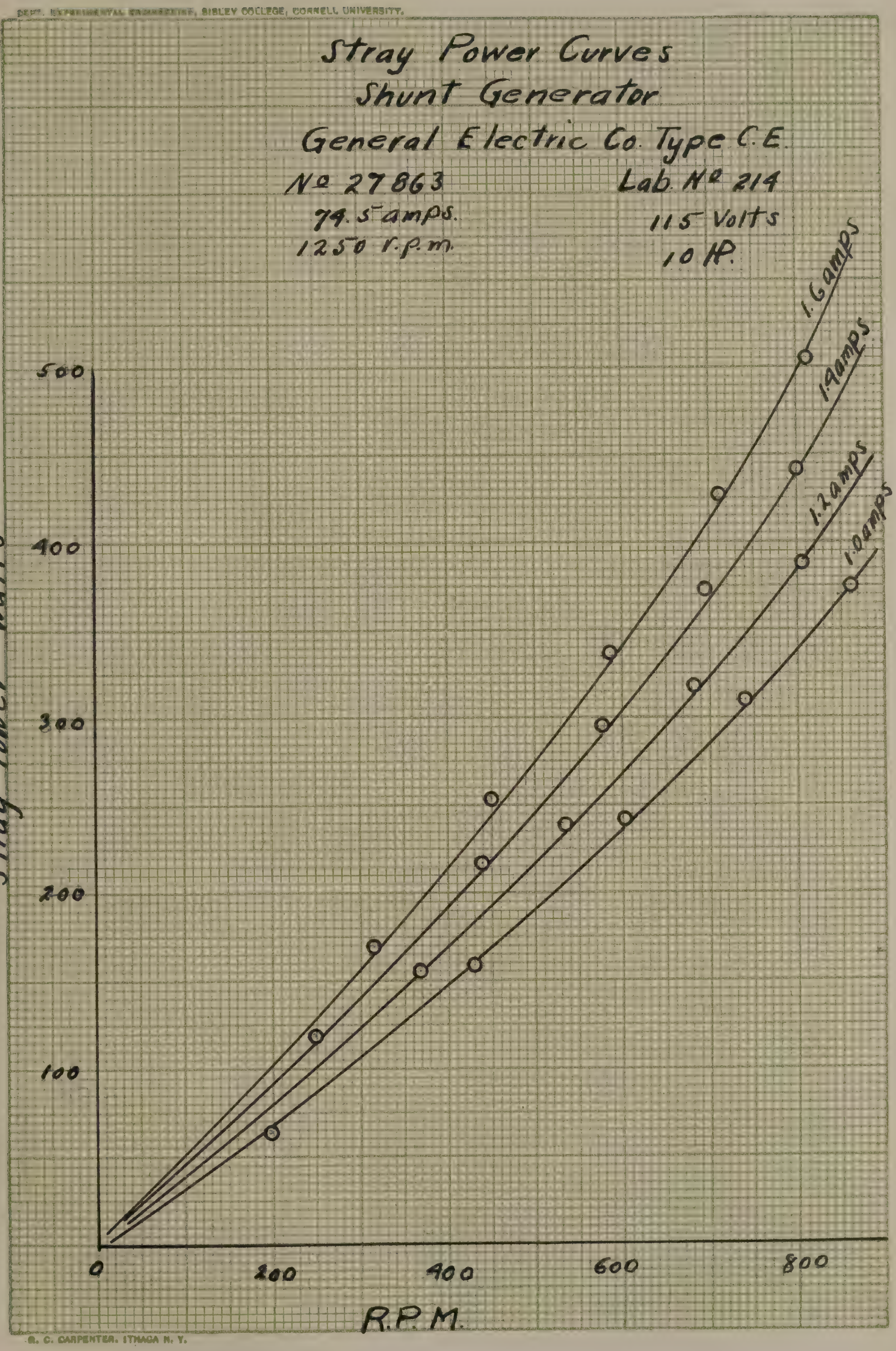
CALIBRATION OF TACHOMETER

TACHOMETER READING	300	400	500	600	700	800	900	1000
ACTUAL R.P.M.	285	388	490	589	695	790	885	992

CALIBRATION OF GENERATOR						
FIELD CURRENT 1.0 amp. ARMATURE RESISTANCE 0.10 ohms						
GEN. R.P.M.	ARM. VOLTS	ARM. AMPS	INPUT in WATTS	$R_a I_a^2$ LOSS WATTS	STRAY POWER LOSS WATTS	STRAY POWER LOSS H.P.
950	84.5	5.10	432.6	2.60	430	0.576
900	81.6	5.00	402.5	2.50	400	0.536
850	77.6	4.92	372.5	2.40	370	0.596
820	76.0	4.50	362.0	2.00	360	0.483
700	68.0	4.30	292.0	1.83	290	0.390
600	59.0	4.10	241.7	1.65	240	0.322
580	56.5	3.90	221.5	1.50	220	0.295

CALIBRATION OF VOLTMETER							
VOLTMETER READING	40	50	60	70	80	90	100
STANDARD READING	41.0	51.2	61.3	71.4	81.6	82.0	102.0

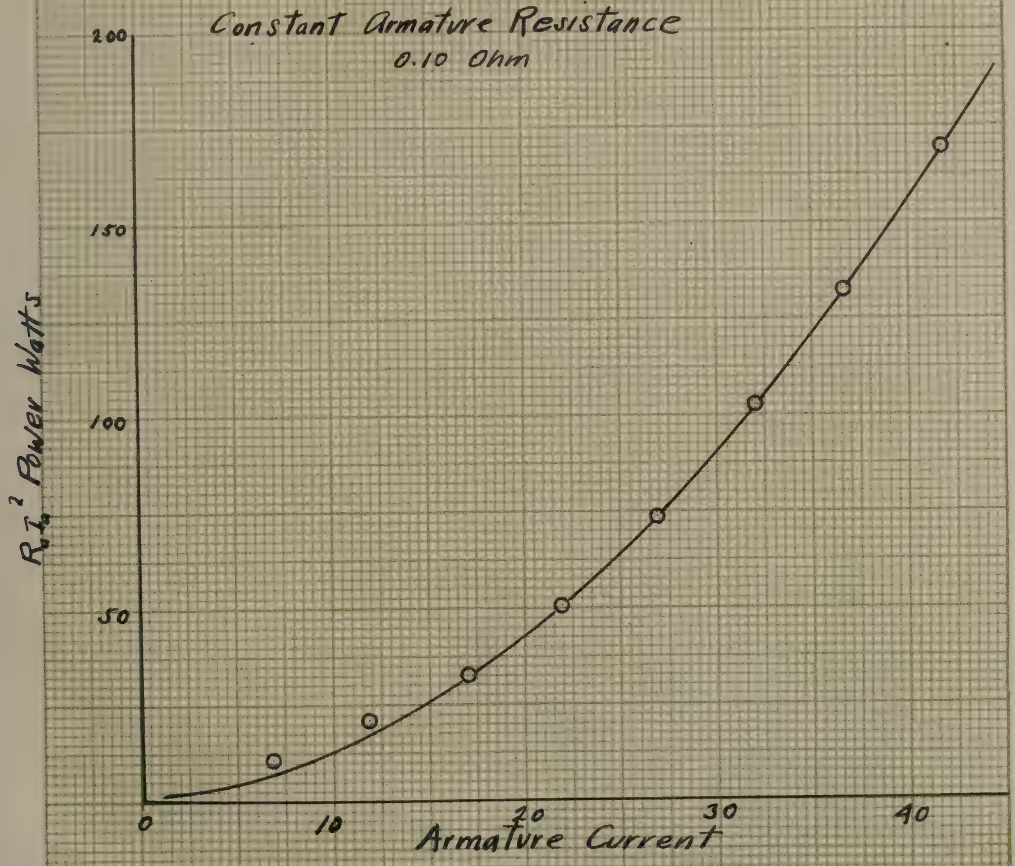
CALIBRATION OF AMMETER					
AMMETER READING	1	2	3	4	5
STANDARD READING	1.04	2.05	3.07	4.07	5.08

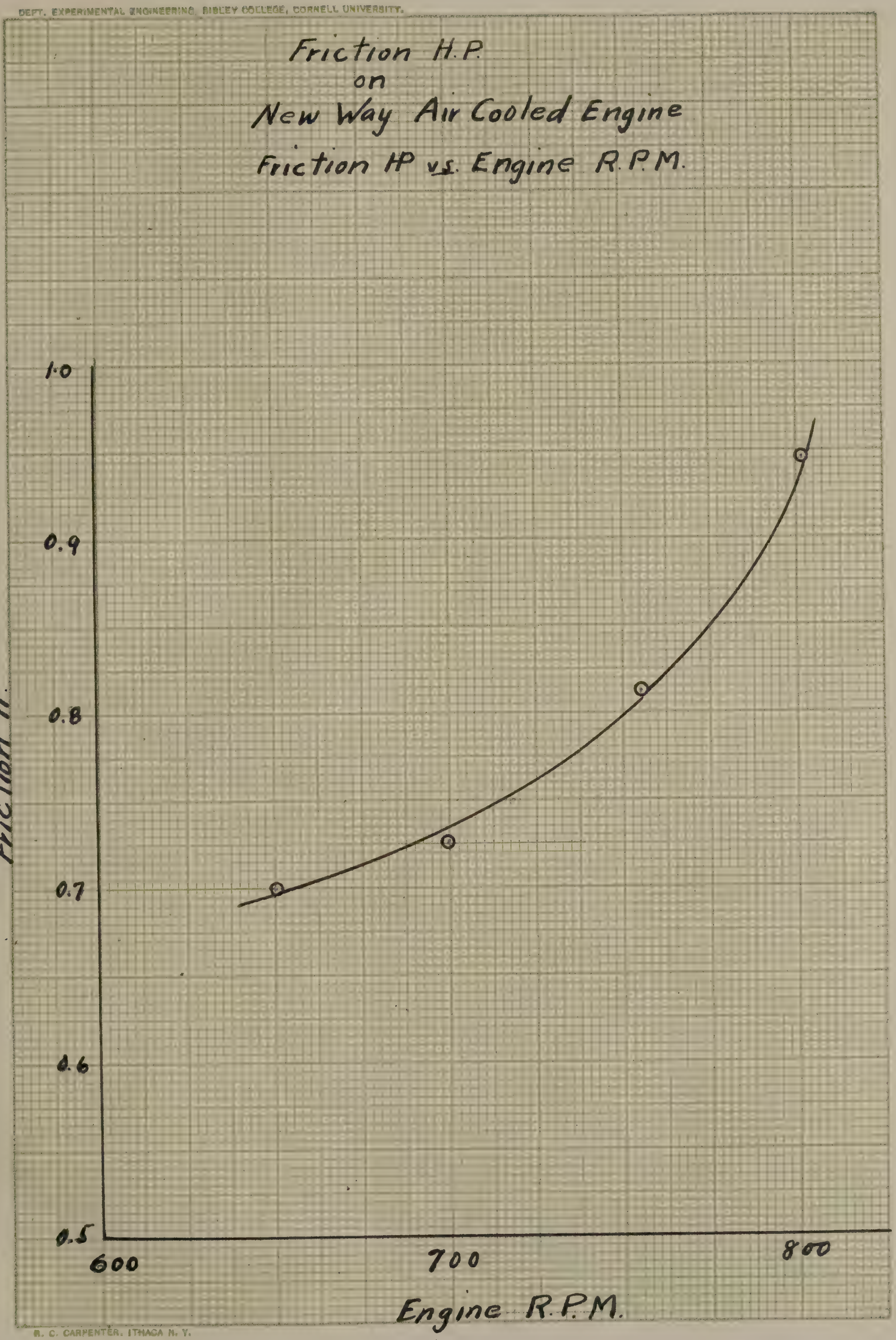

DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
Stray Power Curves
Shunt Generator
General Electric Co. Type C.E.
No 27863
79.5 amps.
1250 r.p.m.
Lab. No 214
115 Volts
10 HP.
1.6 amps
1.4 amps
1.2 amps
1.0 amps
Stray Power Watts
500
400
300
200
100
0
200
400
600
800
R.P.M.
G. C. CARPENTER. ITHACA N. Y.

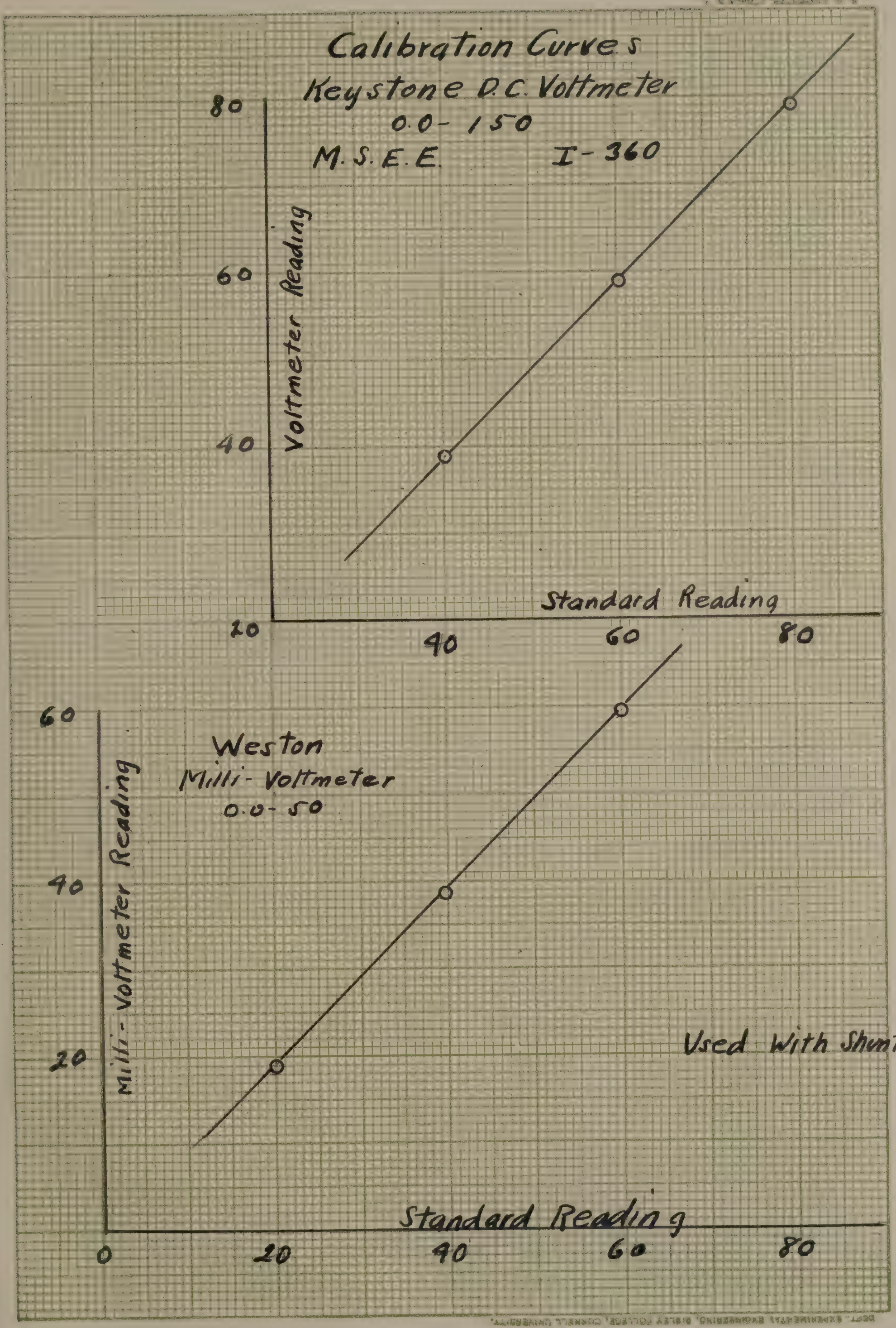
$R_aI_a^2$ Power Curves
Shunt Generator
General Electric Co. Type C.E.
№ 27863 Lab. No 214

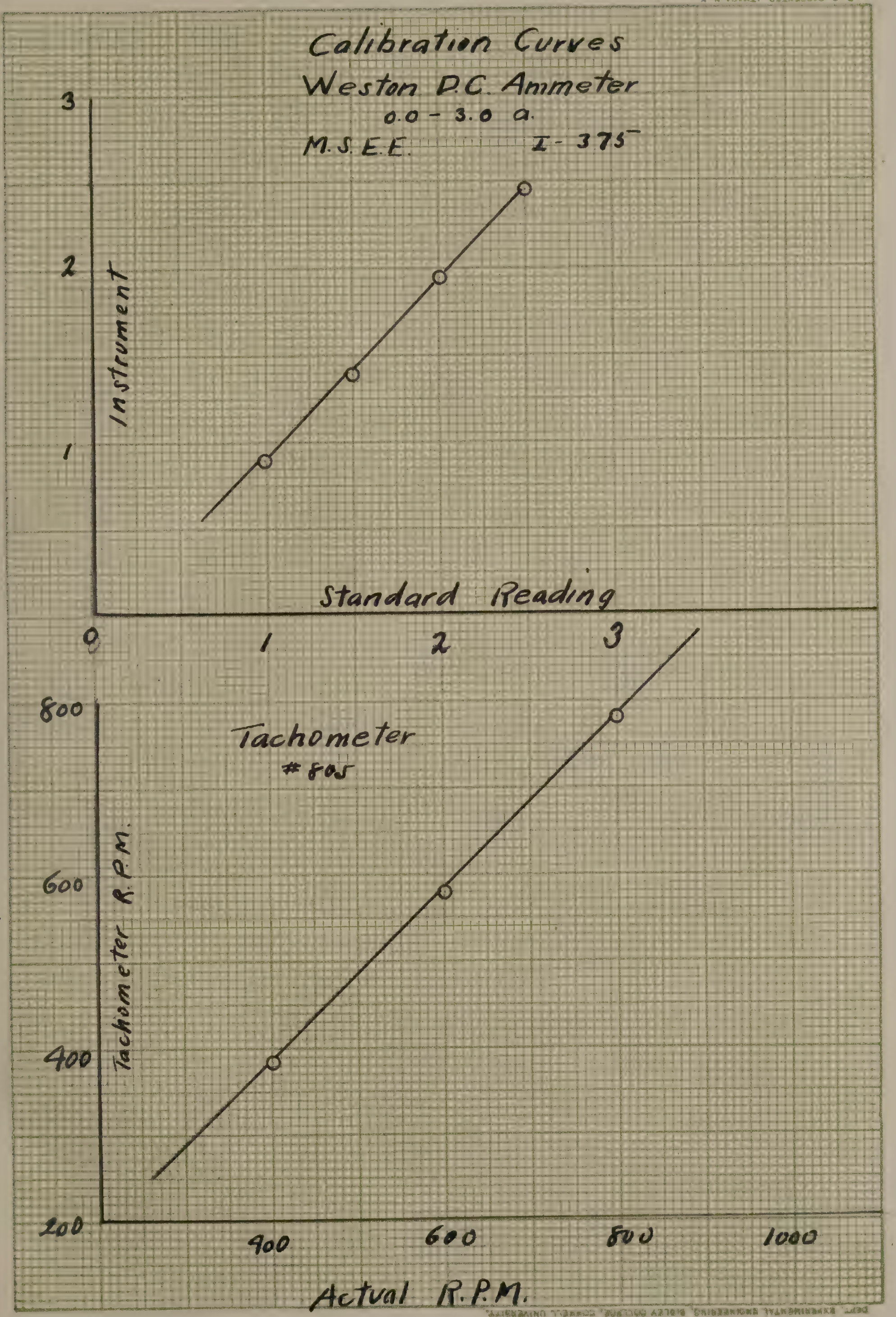
74.5 amps 115 Volts
1250 r.p.m. 10 HP.

RI_a^2 Power vs. Armature Current




DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
Friction H.P.
on
New Way Air Cooled Engine
Friction HP vs. Engine R.P.M.
1.0
0.9
0.8
0.7
0.6
0.5
Friction HP.
600
700
800
Engine R.P.M.
R. C. CARPENTER, ITHACA N. Y.


Calibration Curves
Keystone D.C. Voltmeter
0.0- 150
M.S.E.E.
I- 360
Voltmeter Reading
80
60
40
20
Standard Reading
40
60
80
Weston
Milli- Voltmeter
0.0- 50
Milli- Voltmeter Reading
60
40
20
0
Used With Shunt
Standard Reading
0
20
40
60
80



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